

ECE 480 Point of Sale Grocery Cart

Team 6

Ben Lauzon

Matt Rasmussen

Husain Aleid

Taoping Zhu

Shuangfei Liu

Table of Contents

Introduction	3-4
Background	4-6
Objectives and Design Specifications	6-7
Conceptual Design Descriptions	7-9
Proposed Design Solution	9-10
FAST Diagram	11
Gantt Chart	12
Risks	12-13
Project Management Plan	13-14
Estimated Costs/Cheapest Vendors	14-15

Introduction

The system used in grocery stores around the world is one everyone is familiar with. It is one that has been around for a very long time, and is arguably out of date. The major issue with today's system is the unnecessary stop at the checkout line when a shopper is finished gathering items. It involves a lot of unnecessary waiting. At the front of this line is a cashier who is being paid to remove all the items you just placed into your cart, scan them, and then place them right back where they were. This results in a lot of the shopper's time being wasted, adds to congestion near the store's exit, and adds cost for the store which has to pay cashiers. This system is in dire need of an update.

The goal of the *point of sale grocery cart* is to create an easier system for shoppers to use, while cutting down on the costs for the store. This new system involves placing the scanner normally wielded by the cashier into the hands of every shopper. As a patron of the store travels between aisles and gathers items, they can use their smartphone to scan the items as they put them into their cart. Once an item has been scanned, the cart which is equipped with a set of load cells reads the weight of the item added to the cart and verifies it with the store's database. This helps confirm the correct item was placed in the cart. In case of having the wrong item, the server will send an alarming signal to the phone and thus an alarm will pop up to the customer and will not turn off until an action is taken. When finished shopping, the shopper will be able to use a credit card to checkout directly from their phone. This means they can skip the long checkout lines for good. The carts will be able to leave the store once the customer has checked out. If the customer leaves without paying, an alarm will sound. In addition to the changes to the way a shopper checks out, the system can also automatically apply electronic coupons to the cart

to avoid the chance of the user forgetting them. Lastly, the final product could recommend items to the shopper based on purchasing history and offer incentives to purchase these items again such as coupons. The current checkout system is in desperate need of an update to save time and money for both sides of the grocery store.

Background

Upon researching back as far back as spring of 2011, no other group has done this project or anything similar. As far as other companies that have done a similar design, the only one close is from SK Telecom. They provided a tablet-PC attached to each grocery cart that syncs with the smartphone of the user to provide product information, tips, reminders, and discounts while shopping.¹

A product with an idea that could potentially benefit this design is from thesmartdock.com which gives shoppers a cradle attached to the front of the grocery cart that gives them the ability to conveniently check their smartphone with ease while shopping. A clamp similar to this but attached to the cart could free up one hand for the shopper. If positioned vertically and in a way that the rear-facing camera is aimed over the cart, a shopper would need to only hold the item in front of the camera to scan it before placing it into the cart.

Current self-checkout systems consist of a scanner and one or more load cells.^{2,3} A customer removes items from their cart or basket, scans them, and places them in the bagging

¹ <http://www.engadget.com/2011/07/27/sk-telecoms-smart-cart-syncs-to-phones-reminds-you-to-buy-milk/>

² ftp://ftp.software.ibm.com/software/retail/pubs/hw/selfcheckout/hav1_hw_service_guide.pdf

³ <ftp://ftp.software.ibm.com/software/retail/pubs/hw/selfcheckout/bpc5mst.pdf>

area where each item's weight is checked against a value stored on a server.⁴ If the item's weight matches the stored value, the machine then allows users to continue scanning more items. If not, the user is alerted to the inconsistency and is not allowed to continue checking out items until they resolve the weight mismatch. Additionally, stores typically station one or more employees near the self-checkouts to help users and prevent shoplifting.

A load cell is a device that converts an applied force into an electric signal. Most load cells are strain gauge load cells. They consist of a Wheatstone Bridge of resistive elements which, when deformed by the weight of groceries for example, vary their resistivity. From these variations, a change in voltage directly proportional to the weight of the groceries is produced.⁵ By comparing the value of this voltage before and after an item is placed onto the load cell, the item's weight can be calculated.

At least one company offers a smart phone app capable of reading item barcodes and performing a price check; however, this functionality has not yet been extended to include purchasing. The app also keeps a list of scanned items and lists the total price for a user. The company, NCR, claims this helps shopper's stay aware of their budget as they shop.⁶

A complex challenge for this project will be the inclusion of image processing techniques to identify various non-barcode items. Recent work by graduate students at Michigan State University, with help and sponsorship from IBM, attempts to tackle this problem. Their solution, with the charming name VeggieVision, first photographs the produce a customer wants to buy.

⁴ <http://www.theage.com.au/news/national/a-new-way-to-shop-151-check-it-out-for-yourself/2008/04/21/1208742852723.html?page=fullpage>

⁵ <http://www.transducertechniques.com/wheatstone-bridge.aspx>

⁶ <http://a4a0f6939b58c150df1e-8685fe7e4e24133c371aae6679c184ac.r40.cf1.rackcdn.com/v3/original/self-checkout-mobile-shopper-ds.pdf/31a2ab0992497fb2aa3a67e82de8f156/self-checkout-mobile-shopper-ds.pdf>

Then, by comparing details such as color, shape, and texture with “signatures” recorded into a database, the system presents customers with a list of produce options. The tested system was able to present the correct product selection within the top 4 suggestions in over 95% of the tests and the correct produce was the top suggestion in 84% of tests.⁷ While the system is not yet able to perfectly identify produce without help from the customer, it will certainly save time compared to searching through a list of produce items.

Many tutorials exist online to help develop apps for Android, iOS, and Windows Phone platforms some of which include discussions on building a simple barcode reader.⁸ Additionally, documentation exists that discusses how to send and receive information via Wi-Fi and Bluetooth, which provides plenty of information about connecting to other devices, such as a central store server or a microcontroller on the cart.^{9,10}

Objectives and Design Specification

The aim of this project is to prototype a new, streamlined checkout experience for the everyday shopper. The final design is not expected to be store-deployable but provide a proof-of-concept model for future work. By combining a weight sensing cart with a smartphone app, customers will be able to skip checkout lines by checking themselves out straight from their cart. The new system must use traditional grocery carts with minor additions; this system should allow store owners to refit their current carts rather than buying entirely new ones.

⁷ http://www.cse.msu.edu/~rossarun/courses/sp14/cse802/papers/BolleVeggieVision_WACV96.pdf (Bolle, R.M., Connell, J.H., Haas, N., Mohan, R., Taubin, G.; VeggieVision: A Produce Recognition System)

⁸ <http://code.tutsplus.com/tutorials/android-sdk-create-a-barcode-reader--mobile-17162>

⁹ <http://developer.android.com/reference/android/net/wifi/package-summary.html>

¹⁰ <http://developer.android.com/reference/android/bluetooth/package-summary.html>

The cart additions must be rugged, as they will have to withstand daily abuse from customers as well as weather and temperature-related stresses like cold, rain, and snow. The carts' weight-sensing and communication systems must be powered by a wirelessly rechargeable battery and last a full day on a single charge. The weight sensor placed in the cart must accurately measure weights ranging from an ounce to a full cart of groceries, at least 130 pounds, and must do so reliably no matter where on the cart the item is placed. This imposes both a sensitivity and dynamic range constraint on the weight-sensing system.

The phone application will be used by customers of all technical backgrounds, and therefore must be simple, intuitive, and user friendly. Additionally, the application must be secure against attempts to "hack" it or checkout items of lesser price. The application must also take pictures of produce items and recognize what item is being bought from the picture so that users are not required to manual select from a full list of produce options.

Two additions to current grocery store infrastructure have been allowed. First, WiFi Internet access may be expected from grocery stores. This is done to allow phones to initiate payment transactions; stores in places with poor cell phone data coverage still want users to have a consistent checkout experience so payment over a user's 3G or 4G connection is not sufficient. Second, modification to the cart corral at the store's entrance is allowed so that wireless charging can be accomplished efficiently.

Conceptual Design Descriptions

Many different designs of this project have been discussed and various paths were suggested to follow in order to build a prototype for this project. However, to maximize the proficiency of the project and the ease of troubleshooting, the project was divided into three

separate categories that will be built individually. These categories include Cart Communication Method, Battery Charging Design, and Cart Weighting Mechanism Design.

Cart Communication System 1: The first suggested design for the load cells consists of four major parts: Load Cells, Amplifier, Analog to Digital Converter, and Microcontroller. After the item is scanned by the customer's phone and sent to the load cells, it is amplified and converted to a digital signal. This signal is sent wirelessly to the server which will communicate with the cart and check if that item was placed or not. (See figure 1)

Cart Communication System 2:

The second design will be similar to design 1 except that this design will have an Arduino Uno board that will have a built-in Analog-to-Digital converter device and a microcontroller. It will also be responsible for sending the data to the server through the Wi-Fi network. (See figure 2)

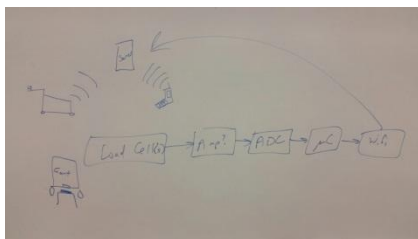


Figure 1

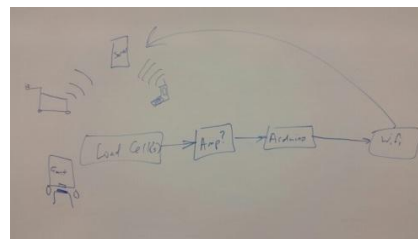


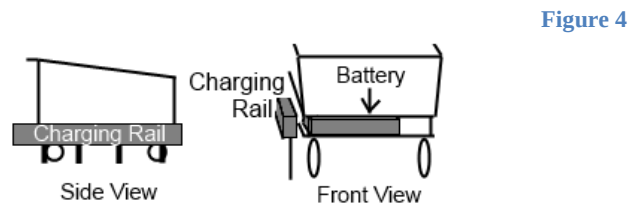
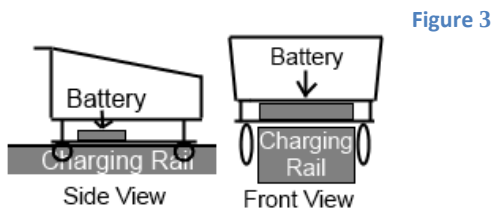
Figure 2

Battery Charging Design 1:

This design consists of a wireless charging mat that will be placed in the center of the cart collecting rack. The customer will push the cart into the rack and the charging mat will take position between the tires of the cart. The charging receiver will be positioned on the bottom of the cart so it can be charged from the mat below. The customers will take carts from the side opposite to that in which the use carts are placed. This will allow enough time for the carts to recharge. (See figure 3)

Battery Charging Design 2: The concept of this design is similar to Design 1, except that the battery will be placed on the side of the cart and the charging mat will be connected to the wall.

(See figure 4)



Load Cell Layout:

The proposed design consists of two load cells that will be placed at the center of the outer edges of the board. These load cells will have square metal mounted platforms on top that will be placed under the large board accurate weight readings can be taken no matter where the item is placed in the cart.

Proposed Design Solution

The proposed design combines selected component designs, discussed above, based on their feasibility. The wireless charging solution chosen involves using a floor-mounted charging rail. While not strictly an addition to the cart only, the design sponsor agreed that this design would be acceptable. Using a rail straddled by the carts' wheels allows the most consistent alignment of wireless charging components and greater charger efficiency.

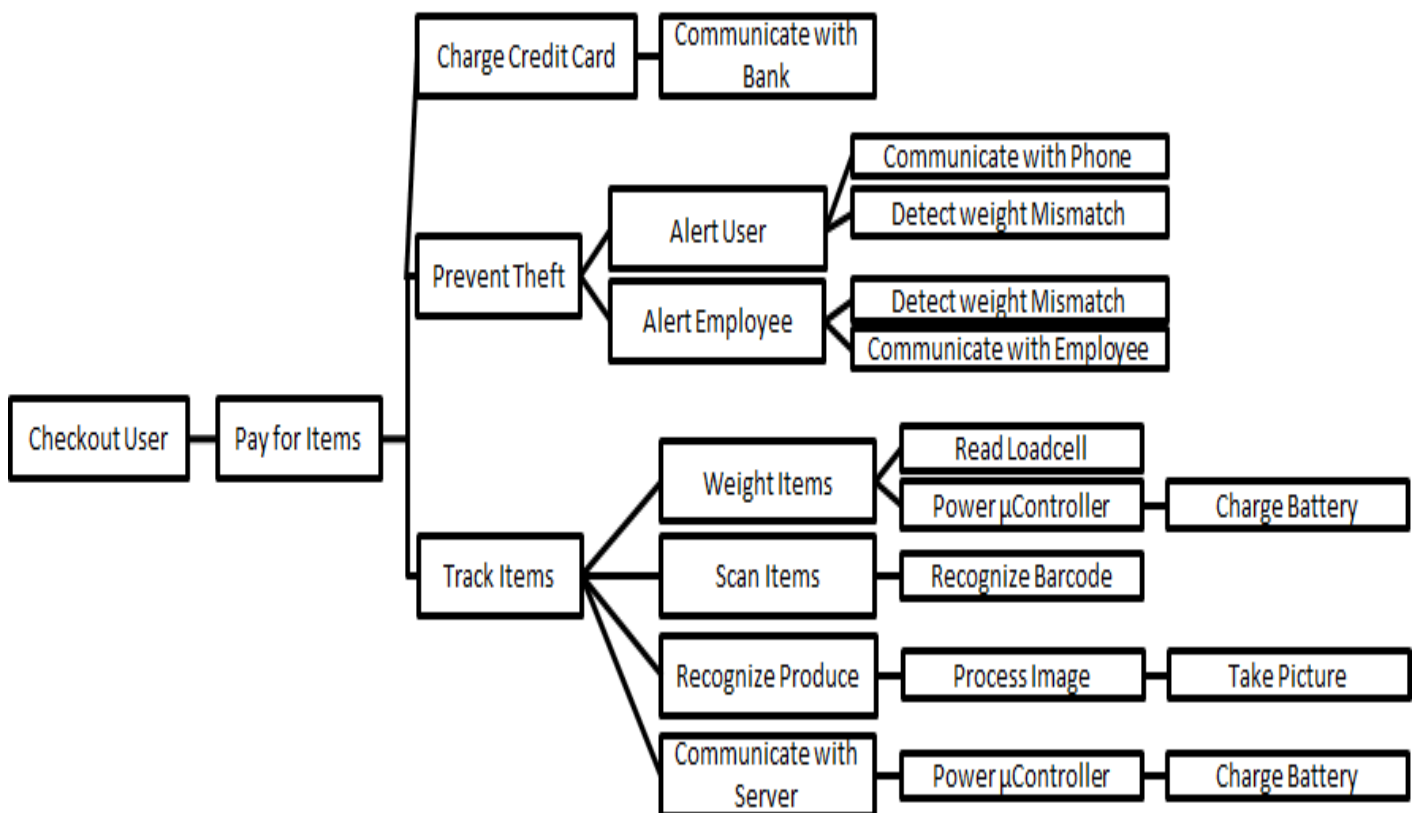
The smartphone application and cart will both communicate wirelessly with a store's server. The server will store receive both weight of items from the cart and the barcode UPC

value from the phone. This is done to prevent users from modifying the weights of items before check out, reducing possible theft. Additionally, it means stores need only update items' prices on the server without requiring users to download a new version of the app during sales and promotions. The server will also accept images from the phone, which it will attempt to process and identify as produce. The suggested produce item will be returned to the phone for the user to approve in case a misidentification has occurred.

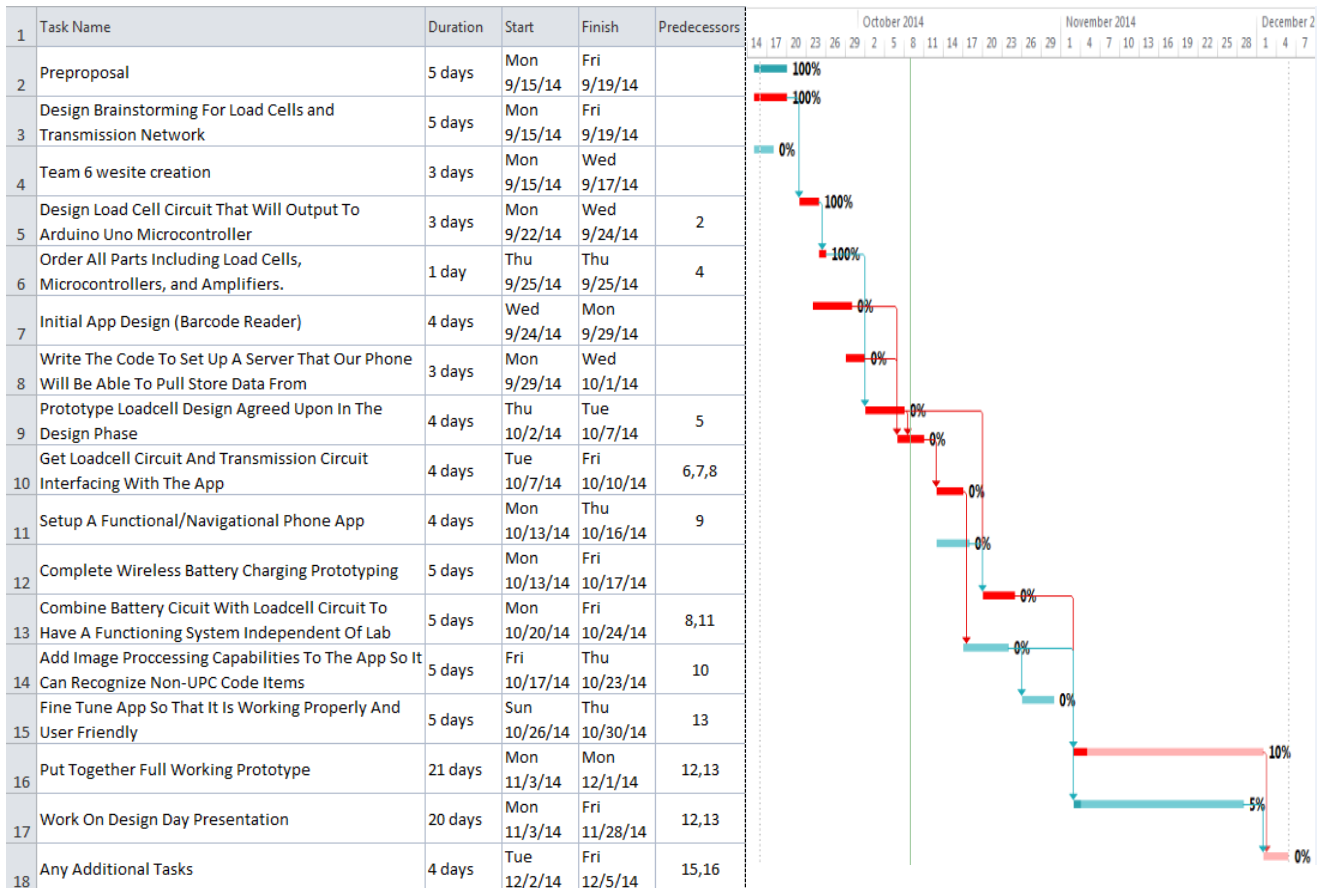
A selection of two load cells placed at opposite ends of the cart was chosen for this design. The load cells selected can handle 65 pounds each, allowing a total 130 pounds to be placed into the cart. Using two load cells minimizes the impact of item position on the scale while increasing the total weight capacity of the system. The signal from the two load cells will be summed and the resulting weight figure will be reported to the server by the cart.

Given the prototype nature of this project, the more expensive Arduino microcontroller was chosen as the cart processing and communication platform. This microcontroller has extensive C libraries that will enable rapid development. If this project matures into a store-deployable system, the microcontroller choice will be revisited as the Texas Instruments product offers a 40% cost savings but does not offer the same libraries and is significantly more difficult to work with.

FAST Diagram



Gantt Chart



Risks

Since the grocery cart design involves the use of a scanner and load cells, there should be some potential risks in the design. The final cart will be more expensive than a traditional grocery cart which means it is more likely to be stolen or dismantled for parts. The team must take special care while designing to ensure that the cart is built in such a way that stealing parts is impractical and difficult. The team will also have to create a safe app that will be very difficult

to hack into. If not, the system could be tampered with. The store could potentially lose a lot of money because of hacking

The cart must also withstand a wide range of temperature levels. The team will use materials that will be able to resist the bitter cold of winter or the blazing heat of summer. The team also faces many challenges when trying to meet the project requirements. These include; designing the protected phone application, weight sensing accurate to the ounce, app ease of use, and accuracy of image processing.

Project Management Plan

Preproposal -	September 15-19	Components Successfully Interfacing -	October 7-10
Design Brainstorming -	September 15-19	App Interface -	October 13-16
Website Creation -	September 15-17	Battery Charge Prototyping -	October 13-17
Initial Circuit Design -	September 22-24	Full Working Load-cell and Battery Circuit -	October 20-24
Part's List -	September 25	Image Processing -	October 17-23
Order Parts -	September 26-October 1	Fine Tuning App -	October 26-30
Initial App Design (Barcode Reader) -	September 24-29	Full Working Prototype -	November 3-December 1

Server Code Setup - September 29- October 1 Presentation - November 3-28

Load-cell Prototyping - October 1-6 Any Additional Tasks - December 1-5

Estimated Costs/Cheapest Vendors

Microcontrollers:

1. Product Name: Arduino Uno

Price: \$28.28

Product Link: goo.gl/jOuz6U
2. Product Name: TI CC3200 Microcontroller with WiFi support

Price: \$30.08

Product Link: goo.gl/uI3qbA
3. Product Name: Arduino WiFi Shield

Price: \$27.95

Product Link: goo.gl/R2AFh6

Load cells:

1. Product Name: Accuteck Heavy Duty Postal Shipping Scale with Extra Large Display

Price: \$21.99 x 2 (quantity) = \$43.98

Product Link: goo.gl/Vk6WOx

Batteries:

1. Product Name: Motorola External Battery (3000mAh)

Price: \$15.99

Product Link: goo.gl/IJThg7

Wireless Charger:

1. Product Name: Wireless Charging 5V 600mA Transmitter & Receiver

Price: \$9.19

Product Link: goo.gl/tvTqTi

General components (resistors, transistors, etc.)

1. Product Name: Step-up DC/DC Convertor (LT1129CQ-3.3#PBF-ND)

Price: \$4.90

Product Link: goo.gl/SzYUs6

Wireless antenna:

1. Product Name: TP-LINK Indoor Desktop Omni-directional Antenna

Price: \$11.84

Product Link: goo.gl/XlksOa